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Soil Fertility Appraisal under Dominant Land Use Systems in North-Eastern Part of Arid Rajasthan

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Abstract: Surface soil samples (0-30 cm depth) in north-eastern part of arid Rajasthan from agriculture (rainfed and irrigated), grazing lands (*orans*) and sand dunes were collected, analyzed and categorized for fertility status. The pH and EC values of the soils ranged from 7.7 to 9.6 and 0.02 to 2.5 dS m^{-1}, respectively. The average organic carbon (OC) content in the soils varied from 0.30 to 6.20 g kg^{-1} with the lowest content in sand dunes (0.07 g kg^{-1}). Whereas, soils under rainfed crops and grazing lands had 1.3 and 1.5 g kg^{-1} OC, respectively. Soils under irrigated crops recorded highest values for OC (2.2 g kg^{-1}). Phosphorus deficiency was spread all over the district. The available potassium content varied from 84 to 551 kg ha^{-1} with a mean values of 212, 161 and 156 kg ha^{-1} in soils under grazing lands, agriculture (irrigated & rainfed crops) and sand dunes, respectively. Deficiency of potassium (<130 kg ha^{-1}) was more pronounced under agriculture than the grazing lands. Soils of the district were adequate in available iron (4.2-30.4 mg kg^{-1}), manganese (5.5-40.5 mg kg^{-1}) and copper (0.22-7.4 mg kg^{-1}). However, zinc content in the soils varied from 0.28 to 5.90 mg kg^{-1} and about 30% of the samples were found deficient. Zinc deficiency was wide-spread both under rainfed and irrigated agriculture. A significant and positive correlation was observed between OC and P, K, Fe, Mn and Zn. However, the available nutrients (P, Fe, Zn and Cu) showed a negative correlation with pH and $CaCO_3$.

Key words: Soil fertility, land use systems, micronutrients, organic carbon, arid Rajasthan.

Soils of hot arid regions are predominantly sandy with poor water retention capacity, low to very low organic carbon, low to medium in available phosphorus and medium to high in available potassium (Gupta *et al*., 2000). Furthermore soils of the region do not receive adequate nutrient replenishment and consequently productivity of the soils is relatively low. Though the improved crop varieties and use of fertilizers and pesticides have increased crop yields in past 15-20 years in the region, but there has not been substantial improvement in soil fertility of the area. Looking in to present scenario, it is very important to understand and analyze the impact of land uses for sustainability of the system. Physical and chemical properties of soil are mainly dependent on land use pattern, soil type, topography and climatic conditions. The present situation, demands the systematic analysis of the influence of different land uses and management practices on soil properties. The information available on these aspects is meager and is mainly based on the widely scattered sampling. Therefore a comprehensive study was undertaken to know the fertility status of soils under different land uses and an attempt was also made to correlate micronutrient content of the soils with other soil properties.

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Materials and Methods

Surface soil samples from Jhunjhunu District (38′ to 28°31′N latitude and 75°02′ to 75°06′E longitude) were collected from dominant land use systems i.e., rainfed and irrigated crop lands, grazing lands and sand dunes. Pearl millet, mung bean, moth bean, clusterbean, sesame and castor by and large are the common rainfed crops in the area. Wheat, barley, mustard, gram and cotton are grown under irrigated conditions, particularly in extreme south-eastern parts of the district. The analysis of physical and chemical characteristics of soils was carried out following standard analytical procedures (Jackson, 1973). The textural class was determined using the USDA textural triangle. The soil reaction (pH of 1:2 soil water suspension) was determined by pH meter (Jackson, 1973). OC and calcium carbonate contents in soils were estimated following methods given by Piper (1966). Available phosphorus was estimated colorimetrically (Olsen *et al.,* 1954) and available potassium by flame photometer after extraction with neutral normal ammonium acetate solution (pH 7.0). The soils were categorized as low, medium and high in OC, P and K as per the criteria given by Muhr *et al*. (1963). Available quantities of iron, manganese, zinc and copper in the soil were extracted with

Table 1. Soil chemical properties under different land use systems

Land use	pH (1:2)	EC (dS m^{-1})	$CaCO_3$ (%)	OC (g kg^{-1})	P (kg ha^{-1})	K
Irrigated	7.7-9.5 (8.5)	0.02-2.4 (0.12)	0.02-8.5 (0.70)	1.2-6.2 (2.2)	5.8-55.5 (18.5)	93-415 (163)
Rainfed	7.5-9.2 (8.5)	0.02-1.2 (0.12)	0.02-3.2 (0.420)	0.50-2.2 (1.3)	2.7-37.2 (13.2)	84-551 (172)
Grazing lands	8.2-9.2 (8.5)	0.05-2.5 (0.45)	0.02-2.5 (0.65)	1.2-3.5 (1.5)	3.5-35.7 (14.5)	124-551 (212)
Sand dunes	8.1-9.0 (8.4)	0.02-0.17 (0.07)	0.03-0.50 (0.16)	0.30-1.5 (0.70)	3.5-18.4 (7.9)	109-184 (156)

Mean values are given in parenthesis.

DTPA reagent (Lindsay and Norvell, 1978) and were determined with the help of atomic absorption spectrophotometer. Simple correlation coefficient values were computed relating micronutrient content with other physico-chemical properties of the soils as suggested by Panse and Sukhatme (1961).

Results and Discussion

The soils under dominant land uses prevailed in the district were studied for macro, micro nutrients and other soil properties in detail. The OC content showed wide variation in the soils under the four dominant land use systems and ranged from 0.30-6.20 g kg^{-1}. The OC content was lowest in soils under dunes (0.03-0.50 g kg^{-1}) followed by soils under rainfed crops (0.50-2.20 g kg^{-1}). The OC in these soils may be low due to low inherent organic matter and very less addition of organic matter under natural conditions. Tillage operations during planting crops, absence of vegetative covers and relatively lower organic matter addition may be responsible for low OC in these soils. The similar results on OC content in dune soils, as well as sandy soils of Churu and Jaisalmer districts of Rajasthan under rainfed cultivations were also reported by Mahesh Kumar *et al.* (2009b) and Sharma *et al.* (2006). Similar observations of about 20-50% loss in OC under most of the agricultural practices under similar agroclimatic situations were also reported from China and Iran (Habbasi *et al.*, 1997; Wu and Tiessen, 2002). The OC content in soils under grazing lands varied from 1.2-3.5 g kg^{-1}. This indicated that the soils under grazing lands (orans) had higher values for OC than soils under rainfed cropping. The vegetative cover round the year, leaf litter addition and its subsequent decomposition under natural conditions probably resulted in high OC in grazing lands than the soils under rainfed cropping and dunes (Singh *et al.*, 2009). Soils under irrigated cropping had the highest OC (1.2-6.2 g kg^{-1}) probably due to crop cover round the year, litter fall and its decomposition, addition of organic matter through external sources such as FYM, compost, etc., and other management practices.

The available phosphorus in the soils showed wide variability in inter as well as intra land use systems and ranged between 2.7 (in rainfed cropping) to 55.5 kg ha^{-1} (in irrigated cropping). Although the soils were deficient in phosphorus throughout the district across the land use systems, but it was more pronounced in dune soils, rainfed crops followed by grazing lands and least in irrigated crops. However, soils under rainfed crops in south-eastern parts of Jhunjhunu, south of Chirawa and north-east of Nawalgarh and Buhana towns were found to be more deficient in phosphorus. Irrigated soils were high in phosphorus content (5.8-55.5 kg ha^{-1}). This may be due to carry over effect of continuous application of phosphate fertilizers in the region. Similar results on impact of different land use systems on fertility in soils of Rajasthan were obtained by Mahesh Kumar *et al.* (2009a), Somsundaram *et al.* (2009) and Singh *et al.* (2009).

Available potassium content was mostly medium to high and varied from 84 to 551 kg ha^{-1}. The potassium content was higher in the soils under

Table 2. Available micronutrients (mg kg^{-1}) under different land use systems

Land use	Fe	Mn	Zn	Cu
Irrigated	4.2-30.4 (7.7)	6.5-40.5 (12.5)	0.35-5.9 (1.2)	0.22-7.4 (1.4)
Rainfed	4.2-18.7 (7.5)	5.5-25.5 (11.8)	0.28-3.6 (0.85)	0.22-7.2 (1.2)
Grazing lands	4.5-14.8 (7.8)	6.9-19.5 (13.3)	0.42-1.58 (0.87)	0.48-2.2 (1.8)
Sand dunes	3.5-22.7 (6.8)	5.6-17.2 (7.6)	0.58-1.26 (0.86)	0.22-2.2 (1.0)

Mean values are given in parenthesis.

grazing lands (124-551 kg ha^{-1}) followed by rainfed cropping (84-551 kg ha^{-1}), irrigated cropping (93-415 kg ha^{-1}) and was the least in dunes (109-184 kg ha^{-1}). This might be due to the root activities of existing vegetation for transporting available potassium to the surface and also through addition of organic matter under natural condition. However, sizable areas in district, with all kinds of land uses, were found deficient in available potassium. About 25% of the samples were deficient in available potassium. Potassium deficiency (<130 kg ha^{-1}) was more pronounced under irrigated agriculture in north and north-west of Jhunjhunu, south and south-east of Chirawa, north-east of Nawalgarh and south-west of Buhana, clearly indicating the depletion in available potassium from the soils and a need for immediate effort to maintain the potassium status of the soils. These results were not in agreement with the earlier workers such as Gupta *et al.* (2000) and Dhir *et al.* (1977) on potassium status in arid soils of Rajasthan. The variation in results on available potassium might be due to depletion of available potassium from the region over a period of last three decades. Since these soils were continuously cultivated for adapted crops like pearl millet, mung bean, moth bean, clusterbean, sesame and castor and occasionally for wheat without any replenishment of potassium to the soils. Thus, continuous cultivation might have resulted in potassium deficiency.

Soils of the district were found to be adequate in available iron, manganese, copper and zinc, barring zinc deficiencies at places. The average available iron content in the irrigated, rainfed, grazing lands and dune soils were 7.7, 7.5, 7.8 and 6.8 mg kg^{-1} (Table 2), respectively. The results showed slightly higher average content of Fe in grazing lands followed by soils under irrigated cropping and least in rainfed soils. In both grazing lands and irrigated cropping the soils had higher values for Fe due to addition of Fe under natural condition through litter fall and its decomposition and external application through inorganic sources. The results were in close agreement with those reported by Mahesh Kumar *et al.* (2009b) and Pradeep Kumar *et al.* (2006). Mn content in the soils varied from 5.5 to 40.5 mg kg^{-1}. Among the land use systems soils under grazing contained higher Mn than the others particularly from dunes and rainfed systems. Zn content in the soils varied from 0.28 to 5.9 mg kg^{-1} and it was relatively higher in the soils under irrigated crops (1.2 mg kg^{-1}) than other soils. This higher content of Zn may be due to application Zn through inorganic and organic sources. About 25% of the total samples were found deficient in Zn. Zinc deficiency was mainly concentrated in the north and north-western parts of Jhunjhunu, north-eastern parts of Nawalgarh and Khetri under both rainfed and irrigated systems. The available Cu in the soils varied from 0.22 to 7.40 mg kg^{-1} and none of the sample was found deficient in the district. Among the land use systems grazing lands recorded higher values of Cu (1.8 mg kg^{-1}). Almost similar results for micronutrient content in the soils have been reported by Sharma and Singh (2001) in the arid soils of Rajasthan under dominant land use systems.

Table 3. Relationship between soil properties and available nutrients

Soil Properties	P	K	Fe	Mn	Zn	Cu
Irrigated agriculture						
pH	-0.181	-0.168	-0.081	0.057	-0.052	-0.100
$CaCO_3$	-0.023	0.177	0.187	-0.107	-0.022	0.085
OC	0.358	0.491	0.475	0.077	0.054	0.370
Rainfed agriculture						
pH	-0.324	-0.172	-0.240	0.016	-0.172	-0.282
$CaCO_3$	-0.154	-0.025	-0.108	0.130	0.102	0.082
OC	0.274	0.367	0.232	0.038	0.174	0.101
Grazing lands						
pH	-0.356	-0.064	-0.311	-0.315	-0.139	-0.041
$CaCO_3$	-0.134	-0.043	-0.023	0.043	-0.200	0.148
OC	0.657	0.385	0.214	0.504	0.444	0.460
Sand dunes (Stabilized)						
pH	-0.098	0.045	-0.176	0.017	-0.186	0.015
$CaCO_3$	-0.272	--	0.010	-0.267	-0.108	0.014
OC	0.328	0.325	0.095	0.316	0.385	0.368

Available phosphorus, potassium, iron, manganese, zinc and copper under all land uses showed a positive relationship with OC (Table 3). The highest correlation between P and OC was observed (r=0.657) in grazing lands, followed by soils under irrigated agricultural system. OC showed a positive correlation with potassium under all the land uses. The highest relationship was observed for irrigated agricultural system (r=0.491) followed by grazing lands (r=0.385). Among the micronutrients, Fe in irrigated lands (0.475), and Mn (r=0.504), Zn (r=0.447) and Cu (r=0.460) observed the highest relationship with OC in grazing lands.

The positive and significant relationship between OC and other nutrients in grazing lands was attributed to continuous addition of organic matter in to the soils under natural conditions. Likewise continuous addition of organic sources under agricultural soils by the farmers leads to positive association of OC with available nutrients. Whereas, soil pH, $CaCO_3$ were negatively correlated with available phosphorus, potassium, iron, manganese, zinc and copper in all of the dominant land use systems prevailed in the district. Similar results on correlations between OC and macro and micronutrients were also reported by Mahesh Kumar *et al.* (2009b) and Sharma *et al.* (2003) while working on arid soils of Jodhpur and Nagaur districts. They also found that like the grazing lands, the tree-based system showed the highest degree of correlation among OC and available nutrients.

Conclusions

Soils of the district were poor in OC content with lowest being in dune soils. However, soils under better management (intensive agriculture) were found superior in OC over other land use systems. Irrigated soils showed the build up of phosphorus. This may be due to carry over effect of continuous application of phosphate fertilizers. The soils under rainfed cropping, grazing lands and dunes were low to medium in phosphorus. Potassium deficiency was distributed all over the district and about 25% of the total samples were found deficient in potassium. The deficiency of potassium was more pronounced in agricultural systems. This clearly indicated that there was depletion of available potassium in the region. Soils were found adequate in micronutrient content except, zinc which was deficient in pockets under agricultural system.

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